Ethnic Disparities and Demographic Shifts in Sarawak's Aging Population: A Comprehensive Longitudinal Analysis (1980-2020)

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Abstract
The aging population constitutes a pivotal demographic shift with substantial implications across social, economic, and healthcare spheres, notably in ethnically diverse territories such as Sarawak, Malaysia. This investigation delivers an exhaustive longitudinal examination of the distribution and demographic trends of the elderly among various ethnic communities in Sarawak from 1980 to 2020. Despite abundant scholarship on population aging, the confluence of ethnicity and aging has received scant attention, particularly within the Malaysian milieu. This research endeavors to bridge this gap by exploring the following question: How have the proportions of senior citizens within Sarawak's diverse ethnic groups evolved from 1980 to 2020? Employing secondary data sourced from the Department of Statistics Malaysia, this study utilises descriptive analysis, linear regression models, and Geographic Information System (GIS) techniques to delineate and expound these trends. The analysis uncovers pronounced disparities in aging trajectories among the ethnic groups. Notably, the Chinese community exhibits the most pronounced and consistent increase in the elderly population, while the Iban and other indigenous cohorts show a decline, possibly attributable to migration and diminished fertility rates. Conversely, the burgeoning proportion of elderly Malays indicates enhancements in health and socio-economic statuses, contrasting with the steady figures observed within the Chinese and Indian communities, which likely reflect enduring cultural traditions such as filial piety. These findings underscore the imperative for culturally attuned policies and interventions tailored to the distinct needs of each ethnic group as Sarawak's demographic landscape ages. This study underscores the importance of recognizing ethnic-specific aging patterns for efficacious public health and social service strategy formulation in a culturally heterogeneous region like Sarawak. By integrating insights into the spatial dynamics of aging, anchored by Tobler's First Law of Geography, this research contributes novel perspectives to the body of knowledge and supports the creation of more effective and inclusive policies.

Keywords: Aging Population, Demographic Trends, Ethnic Disparities, Geographic Information System (GIS), Senior Citizens

1. Introduction
The demographic composition of the globe is shifting markedly as the proportion of older adults escalates, a phenomenon commonly referred to as "global aging." This shift has profound implications for social, economic, and healthcare systems worldwide. The United Nations projects that the population aged 65 and over will expand from 703 million in 2019 to over 1.5 billion by 2050. Particularly pronounced in developed regions like Europe and Japan, where the elderly constitute over 20% of the population, this demographic transformation is reshaping societies. Conversely, in developing regions such as parts of Asia, the growth in the elderly population is more gradual yet steadily increasing, driven by enhanced longevity and declining birth rates [1]. These changes necessitate comprehensive strategies to address the needs of an aging populace, presenting challenges to healthcare provisions, pension systems, and labor markets.

In Asia, Malaysia mirrors global trends with its demographic shifts, with projections indicating that by 2030, the elderly will make up 15.3% of the nation's total population [2]. Within this context, Sarawak, a state on the island of Borneo, offers a compelling case study due to its distinct geographic and demographic profiles. Unlike more homogeneous regions, Sarawak is characterized by its rich ethnic diversity, including major groups such as Malays, Iban, Bidayuh, Melanau, Chinese, and others. This diversity provides a unique laboratory for studying how different cultural and socio-economic backgrounds influence aging. Sarawak's geographical features vary from dense urban centers to remote rural areas, creating varied living conditions that affect the health and social services accessible to its aging population. These factors make Sarawak an ideal locale to explore the multifaceted impacts of aging across different communities, examining how geographic and ethnic diversity influences aging experiences and needs.

Despite the increasing importance of demographic studies in Malaysia, research specifically exploring the intersection of ethnicity and aging within Sarawak remains limited. This study aims to fill that gap by addressing the critical question: How has the proportion of elderly individuals across different ethnic groups in Sarawak evolved from 1980 to 2020? By analyzing the trends in the distribution of the elderly among these diverse ethnic groups over the past four decades, this research offers insights that can inform targeted and culturally attuned policy interventions. Employing secondary data sourced from the Department of Statistics Malaysia (DoSM), this study utilizes descriptive statistics, linear regression models, and Geographic Information Systems (GIS) technology to visualize and analyze the spatial distribution of the elderly population across Sarawak. This approach not only aids in identifying key trends but also facilitates an exploration of the factors contributing to these patterns, enhancing our understanding of how demographic changes are dispersed geographically throughout the state.

By focusing on Sarawak's unique context, this study provides valuable insights into the dynamics of aging in a multi-ethnic society, contributing to the broader discourse on aging and public policy. The findings are relevant for Sarawak and applicable to other regions with similar demographic profiles, making a significant contribution to demography and public health. The spatial distribution of the elderly population is crucial for comprehending regional demographic shifts. Prior studies have demonstrated that demographic transitions significantly influence various socio-economic conditions, which in turn impact regional dynamics [3]. For instance, spatial analysis has been instrumental in examining the relationship between population distribution and socio-economic phenomena, uncovering complex patterns that inform public policy and further underscoring the value of geospatial assessments in public health planning, especially in areas with diverse populations [4] and [5]. As populations age, different regions may experience varying aging rates due to socio-economic, cultural, and environmental factors. Understanding these patterns is crucial for devising effective public policies and ensuring equitable distribution of services, including healthcare and social support.

According to Tobler's First Law of Geography, 'everything is related to everything else, but near things are more related than distant things.' This principle is pivotal in understanding spatial relationships and has been guiding the interpretation of geographical data in our study. While our analysis primarily involves descriptive statistics and geographic mapping without the use of advanced spatial statistical techniques such as spatial autocorrelation or cluster analysis, the Law provides a theoretical basis for expecting that demographic characteristics will be more similar within geographically proximate areas than between more distant ones. While existing literature on aging in Malaysia primarily focuses on national or urban scenarios, this study addresses a significant gap by providing a detailed, longitudinal analysis of aging trends across different ethnic groups in Sarawak. By integrating ethnic dimensions into demographic research, this study offers valuable insights that can guide culturally sensitive policymaking. Moreover, employing GIS technology to map and analyze the spatial distribution of the elderly represents a methodological advance in demographic studies, showcasing the utility of spatial analysis in this field.

The findings from this study have significant implications for public policy and social services in Sarawak. Recognizing ethnic-specific aging trends is essential for developing targeted interventions that address the unique challenges faced by different communities within the state. Identifying areas with high concentrations of elderly populations can inform resource allocation for healthcare, social support, and infrastructure development.

Additionally, the insights from this study are applicable in other regions with similar demographic profiles, rendering this research relevant not only to Sarawak but also to other multi-ethnic societies grappling with the challenges of an aging population.

This paper is organized as follows: The next section, the Literature Review, delves into existing research on population aging, with a focus on ethnic disparities and the application of spatial analysis in demographic studies. This is followed by the Methods section, which details the data sources, analytical approaches, and the theoretical underpinnings of the study, particularly Tobler's First Law of Geography. The Results section presents key findings on the trends in the distribution of senior citizens across different ethnic groups in Sarawak from 1980 to 2020. In the Discussion section, these findings are interpreted considering the existing literature and the research question, emphasizing the implications for public policy and socio-economic planning. The paper concludes with a summary of the main insights, the significance of the study, and recommendations for future research.

2. Literature Review

Population aging is a critical demographic trend that has received significant attention worldwide. As global life expectancy increases and fertility rates decline, the proportion of elderly individuals continues to rise, presenting various social, economic, and healthcare challenges [1]. By 2050, one in six people will be aged 65 or over, a significant increase from one in eleven in 2019 [6]. This shift is most pronounced in developed regions such as Europe and East Asia, where citizens the elderly already account for more than 20% of the total population. The implications of this demographic shift are profound, affecting everything from the labor market and economic growth to the demand for health care and social services. Recent studies have further highlighted how spatial distribution, and demographic factors significantly affect regional socio-economic dynamics, with particular emphasis on the implications for public policy and urban planning [3] and [5]. In response, governments and policymakers are increasingly focusing on developing strategies to manage the needs of an aging population, emphasizing the importance of healthy aging, social protection, and an age-friendly environment [6].

2.1 Ethnicity and Aging

The intersection of ethnicity and aging is a growing field of research that seeks to understand how different cultural, social, and economic factors influence the aging process across diverse ethnic groups. Ethnic differences in aging can manifest in many ways, including differences in life expectancy, health outcomes, and access to social services and health care. Studies have shown that cultural practices, socioeconomic status, and historical context significantly shape the experience of aging in ethnic communities [7]. For example, demographic dynamics, such as population density and socioeconomic conditions, have a major impact on how ethnic groups experience aging and access essential services [4]. In a multi-ethnic society such as Malaysia, the aging process can vary widely between ethnic groups due to differences in lifestyle, healthcare access, and community support systems [8]. These differences emphasize the need for culturally sensitive approaches to aging that recognize and address the unique challenges faced by different ethnic groups. Understanding these ethnically specific aging patterns is important for developing targeted policies and interventions that ensure equitable support for all aging populations, leading to more effective public health strategies tailored to the diverse cultural landscape of Sarawak.

2.2 Aging in Malaysia and Sarawak

Malaysia, like many other countries in Southeast Asia, is experiencing rapid demographic change as its population grows. The percentage of elderly people in Malaysia has increased continuously, with projections showing that by 2030, approximately 15.3% of the population will be aged 65 and above [2]. Sarawak presents a unique case in Malaysia due to its ethnic diversity and distinct geographical features. The state is home to several major ethnic groups, including the Malay, Iban, Bidayuh, Melanau, and Chinese, each with its own cultural traditions and social structures. This diversity is reflected in the aging patterns observed across the state, with some ethnic groups experiencing faster rates of aging than others [9]. Studies focusing on Sarawak's aging population have highlighted significant disparities in health outcomes, access to health care, and social support systems across different ethnic communities. [5] further emphasize the importance of geospatial analysis in identifying these gaps, especially in rural areas where access to services may be limited. These findings indicate that ethnic-specific factors, such as cultural practices and economic conditions, play an important role in shaping the aging experience in Sarawak [10]. The distinct patterns of aging observed among Sarawak's diverse ethnic groups underscore the necessity for localized policy interventions, suggesting that future research should explore the nuanced impacts of these demographic shifts on local and regional development strategies.

2.3 Spatial Distribution and Aging

The spatial distribution of the aging population is a critical factor in understanding how the demographic transition affects different regions and communities. Geographic Information Systems (GIS) have become an important tool in demographic research, enabling detailed analysis of how aging populations are distributed across space and how these patterns develop over time [11]. In Malaysia, and particularly in Sarawak, GIS has been used to map the distribution of elderly people across various districts, revealing significant disparities in how different regions experience aging [9]. Urban centers in Sarawak, such as Kuching and Miri, tend to have higher concentrations of elderly populations, which can be attributed to better access to healthcare facilities, social services, and economic opportunities. In contrast, rural areas often have a lower density of seniors, reflecting challenges related to accessibility, infrastructure, and service provision [12]. The utility of GIS has been demonstrated in analyzing spatial patterns, providing a framework for identifying areas that may require targeted interventions to effectively support their aging populations [3] and [5]. However, there is still a need for more comprehensive spatial analysis that integrates ethnic data to better understand how different ethnic groups are distributed across these spatial patterns and what the implications are for policy and planning, paving the way for targeted efficient public health interventions.

Despite the growing body of research on aging populations and the use of GIS in demographic studies, significant gaps remain, especially in the context of a multi-ethnic region like Sarawak. Although several studies have explored the general trends of aging in Malaysia, there is a lack of detailed and longitudinal research that specifically focuses on ethnic differences in aging in Sarawak. Most existing research either addresses aging at the national level or focuses on urban areas, ignoring the unique demographic dynamics in rural areas and among different ethnic groups. Additionally, although GIS has been used to map the distribution of aging populations, there is a lack of studies that combine this spatial analysis with the examination of ethnic-specific trends [8]. This gap in the literature highlights the need for a more integrated research approach that considers both the spatial and ethnic dimensions of aging. By addressing this gap, future research can provide a more nuanced picture of the aging process in Sarawak, informing policies and interventions that are more tailored to the diverse needs of the aging population. The theoritical framework for this study illustrates in Table 1.

2.4 Tobler's First Law of Geography

Tobler's First Law of Geography, introduced by Waldo R. Tobler in 1969, states that "everything is related to everything else, but things that are close are more related than things that are far away." This principle, often referred to as the basis of spatial analysis, suggests that spatial interactions and relationships are stronger among entities that are geographically close than those that are distant [13]. This concept of distance decay in which interaction intensity decreases with increasing distance provides a critical framework for understanding the spatial distribution patterns of populations, including the elderly.

In the context of Sarawak's aging population, Tobler's First Law offers valuable insights into the distribution of the elderly across various districts from 1980 to 2020. The law implies that neighboring districts are more likely to show similar demographic patterns due to socio-shared economy environmental and cultural characteristics. These similarities driven by proximity are especially relevant when studying how different ethnic groups experience aging and how these patterns evolve. Previous studies have used GIS and spatial analysis to explore the distribution of the elderly in various global contexts, revealing that urban centers, with their concentrated amenities, often serve as hubs for older populations [14] and [15]. However, Tobler's Law suggests that in addition to urbanization, the spatial distribution of the elderly may also be influenced by the proximity of districts with similar ethnic composition and socio-economic conditions. In Sarawak, where the population is ethnically diverse and geographically dispersed, this law could help explain the clustering of the elderly population in certain areas and the disparities observed across different ethnic groups.

For example, if a certain district with a high concentration of a certain ethnic group also shows a higher density of elderly people, this may indicate spatial autocorrelation influenced by cultural, economic, or social factors specific to that group. Understanding these spatial relationships can guide more effective policy interventions, ensuring that resources are efficiently allocated to support an aging population across Sarawak's diverse districts. Using Tobler's First Law of Geography, this study seeks to explain the spatial dynamics of aging in Sarawak, revealing how proximity affects the distribution of the elderly and the interaction between ethnicity and geography. This theoretical framework not only improves our understanding of spatial patterns but also provides a basis for developing targeted strategies to address the needs of older people in areas where these dynamics are most pronounced.

Table 1: Theoretical framework

Concept	Description	Application in the Study
Tobler's First Law of Geography	Everything is related to everything else, but near things are more related than distant things.	Explains the spatial clustering of senior citizens in Sarawak, with districts nearby exhibiting similar aging patterns due to shared socio-economic and cultural factors.
Distance Decay	The intensity of interactions between locations decreases as the distance between them increases.	Observes how elderly populations in geographically closer districts may share more similarities in demographic characteristics compared to those further apart.
Ethnic and Socio-Economic Factors	Cultural, social, and economic conditions that vary by district and influence population distribution patterns.	Analyzes how ethnic composition and socio-economic conditions contribute to the spatial patterns observed in the distribution of senior citizens in Sarawak.
Implications for Policy	Understanding spatial relationships is crucial for effective resource allocation and policy planning.	Provides a framework for developing targeted interventions that address the specific needs of senior citizens in both densely populated and remote districts.

3. Methods

3.1 Study Area

Sarawak, the largest state in Malaysia, is located on the northwest coast of the island of Borneo. It covers an area of approximately 124,450 square kilometers, accounting for 34.5% of the country's total area [16]. Sarawak is known for its diverse cultural landscape, housing various ethnic groups, including Malays, Iban, Bidayuh, Melanau, Chinese, and others. The state's unique geographical features, ranging from urban centers like Kuching and Miri to remote rural areas, significantly influence the distribution of its population, including senior citizens. This study focuses on analyzing the distribution and demographic trends of the elderly population across different ethnic groups in Sarawak from 1980 to 2020 [12].

Figure 1 shows a map of Sarawak from 1980 to 2020. The map shows the changes that have occurred to the border areas on the map of Sarawak. In 1980, Sarawak had a total of 25 districts and increased to 27 districts shown in red on the 1991 map, including Samarahan and Tatau districts. In 2000, Sarawak had 29 districts represented by the purple color on the map which included the districts of Matu and Asajaya. In 2010, the districts in Sarawak increased to 31 districts with the inclusion of Pakan and Selangau districts shown on the map represented in green. Next, Sarawak in 2020 shows an increase in districts with a total of 40 districts shown in Figure 1.

The map of Sarawak in 2020 is each represented by the color that shows the new district in that year, and 2020 is defined by the yellow color that shows the districts of Telang Usan, Beluru, Subis, Bukit Mabong, Sebauh, Tanjung Manis, Pusa, Tebedu, and Kabong.

3.2 Research Methodology Flowchart

Figure 2 illustrates the step-by-step methodology followed in this study, encompassing data collection, processing, analysis, and interpretation phases.

3.3 Data Source

This study mainly relies on secondary data obtained from the Department of Statistics Malaysia (DoSM), which provides comprehensive demographic data for Sarawak from 1980 to 2020. This data set includes population counts disaggregated by age of the elderly 65 years and above, ethnicity, and geographical location in Sarawak, allowing detailed analysis of the aging population across different ethnic groups over four decades [17]. The use of such longitudinal data allows the study to track changes in population distribution, density, and the proportion of senior citizens (aged 65 and over) within the state's districts over time. The availability of these data is essential to conducting both spatial and statistical analyses, facilitating the exploration of geographic and ethnic intersections in the aging process in Sarawak.
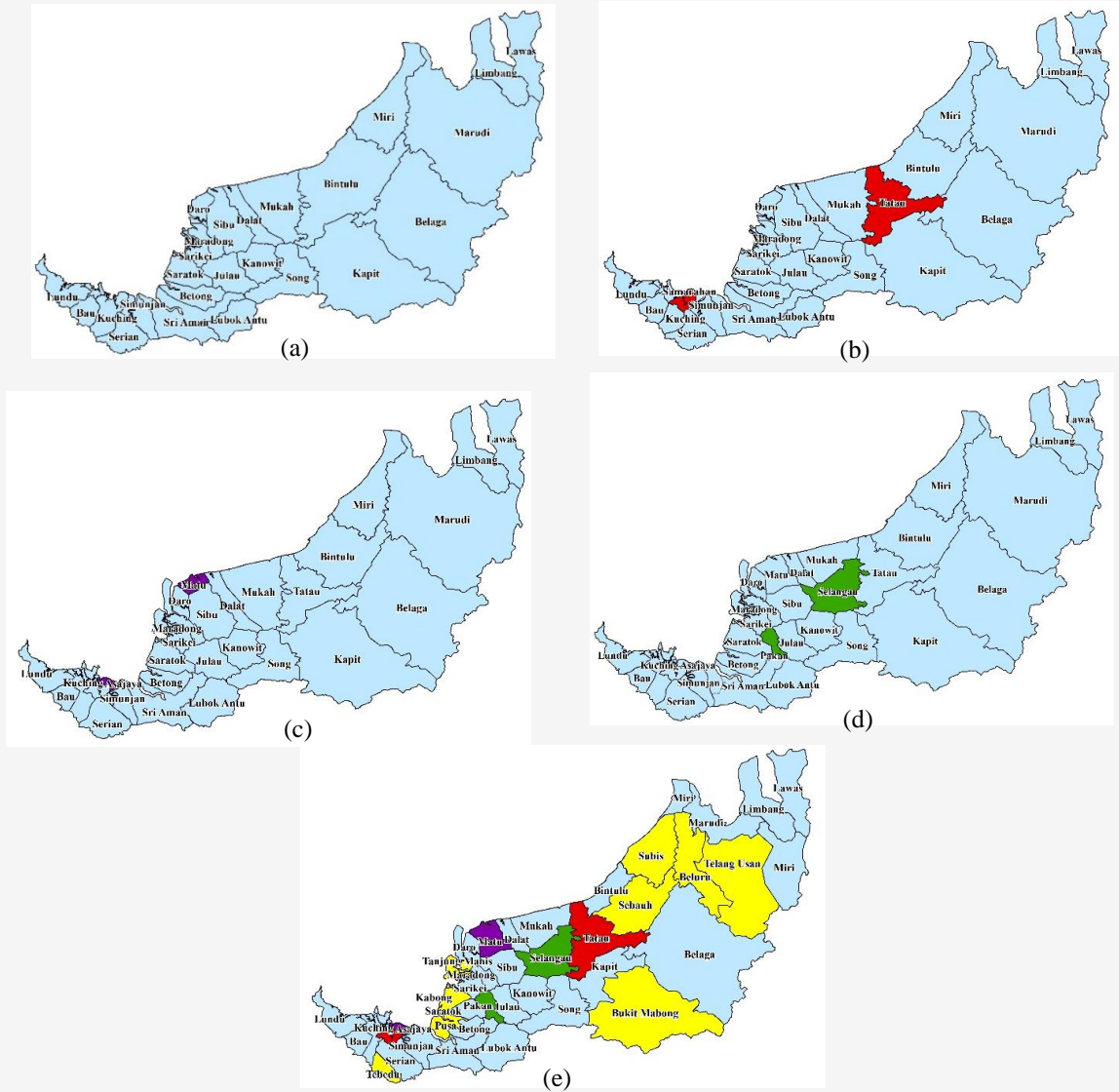
Figure 1: Sarawak District boundaries:
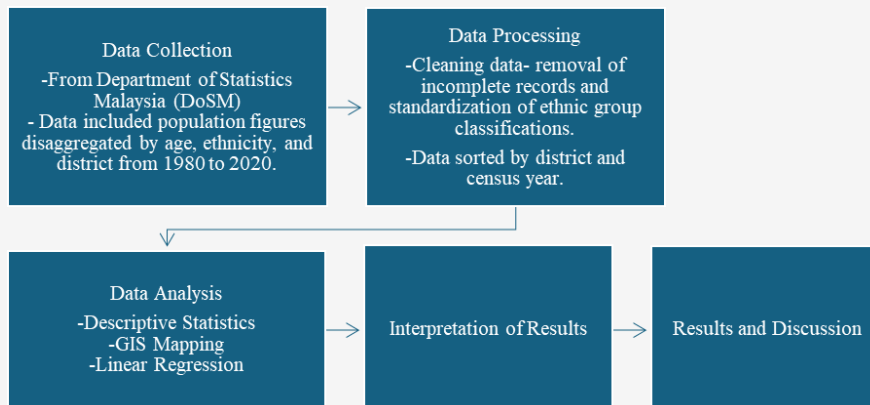(a) 1980 (b) 1991 (c) 2000 (d) 2010 (e) 2020

Figure 2: Research methodology

Given the constraints of our data, full application of spatial statistical techniques was not feasible. Additionally, the scope of available resources and the focus of our initial research questions directed us toward methods that could robustly support our investigation within these constraints. Thus, while spatial autocorrelation and cluster analyses provide deep insights into spatial dependencies, their exclusion from this study does not detract from the validity of the observed geographical patterns of aging populations across Sarawak.

3.4 Statistical Analysis
3.4.1 Descriptive analysis
In the study of demographic trends among the elderly in Sarawak, descriptive analysis was used to understand changes in the composition and characteristics of the elderly population aged 65 and over across different ethnic groups over four decades. This chapter details the specific techniques used to calculate and analyze the proportion and percentage change of the elderly in each ethnic group for each census year studied (1980, 1991, 2000, 2010, and 2020). The main step in the analysis is the calculation of the elderly, defined as individuals aged 65 and over in each ethnic group for a given census year. The elderly proportion is obtained using Equation 1.

$$P = \frac{E}{N} \times 100$$

Equation 1

Where:
 P is the elderly proportion in each ethnic group
 E is the number of elderly in each ethnic group
 N is the total number of elderly

This calculation is done separately for each ethnic group (Malay, Chinese, Iban, Bidayuh, Melanau, Other Bumiputera, Indian, and Others) in each designated census year. By determining these proportions, it is possible to assess the relative size of the elderly population aged 65 and over in each ethnic group, providing insight into the demographic structure and aging patterns of society.

Having established the proportion of elderly people in each ethnic group for each census year, the next step is to calculate the percentage change in this proportion between successive census years. This measure helps identify trends such as increases or decreases in the proportion of seniors aged 65 and over in each ethnic group over time. The percentage change is calculated using Equation 2.

$$\%Change = \frac{P_i - P_f}{P_i} \times 100$$

Equation 2

Where:
 P_i = elderly proportion in the initial year
 P_f = elderly proportion in the final elderly

This calculation is applied between each pair of consecutive census years (ie, 1980 to 1991, 1991 to 2000, 2000 to 2010, and 2010 to 2020). By calculating these percentage changes, it is possible to trace the elderly population across different ethnic communities, highlighting significant demographic shifts that may have implications for social planning and policymaking.

3.4.2 Spatial analysis
The spatial analysis in this study is informed by Tobler's First Law of Geography, which states that "everything is related to everything else, but things that are close are more related than things that are far away" [13]. This principle suggests that the distribution of the elderly population across the districts of Sarawak is likely to be influenced by the distance of these districts from each other, with neighboring areas potentially exhibiting similar demographic patterns due to shared socio-economic and cultural factors. The spatial distribution of the elderly was analyzed using Geographic Information System (GIS) tools, specifically ArcGIS 10.8.2. This approach enables the visualization of the geographical distribution of the elderly population throughout the districts of Sarawak, identifying areas with large numbers of elderly people over time. County boundary maps for each census year were digitized and overlaid with demographic data to create detailed spatial distribution maps. These maps provide a visual representation of demographic shifts, making it easier to identify trends in an aging population.

3.4.3 Linear regression analysis
Linear regression is a powerful statistical method used to model the relationship between a dependent variable and one or more independent variables [18]. This method is particularly useful for examining trends over time, making it an ideal choice for analyzing the changes in the proportion of senior citizens across different ethnic groups [19] and [20]. The selection of linear regression in this research analysis is to determine whether there is a significant trend or not in the proportion of senior citizens in each ethnic group throughout the period from 1980 to 2020.

By establishing the nature of this trend, whether increasing, decreasing, or stable, stakeholders can better understand the aging pattern in each ethnic community in Sarawak. Linear regression attempts to analyze the relationship between two variables by fitting a linear equation to the observed data [21] and [22]. One variable is considered the explanatory (independent) variable, and the other is considered the dependent variable [23] and [24]. The linear regression model that will be used in this analysis is expressed by the following Equation 1:

$$Y_i = \beta_0 + \beta_1 X_i + \epsilon_i$$

Equation 3

Where: Y_i represents the proportion of senior citizens within an ethnic group in a year i, X_i represents the year, β_0 is the intercept of the regression line, representing the estimated proportion of senior citizens at the beginning of the study period (1980), β_1 is the slope of the regression line, indicating the rate of change in the proportion of senior citizens per year, ϵ_i is the error term, capturing all other factors that influence the proportion but are not included in the model.

The integration of GIS-based spatial analysis with descriptive statistics and linear regression methods provides a comprehensive approach to understanding the spatial distribution of Sarawak's elderly population. Grounding this analysis in Tobler's First Law of Geography allows the study to highlight the spatial dynamics that shape demographic trends, thereby offering valuable insights into developing more effective and culturally sensitive policy interventions for Sarawak's aging population.

4. Results
4.1 Spatial Distribution of the Elderly in Sarawak
Figure 3 below shows a map of the distribution of the elderly in Sarawak for the years 1980 to 2020, the geographical variation of the distribution of the elderly in various districts can be seen.
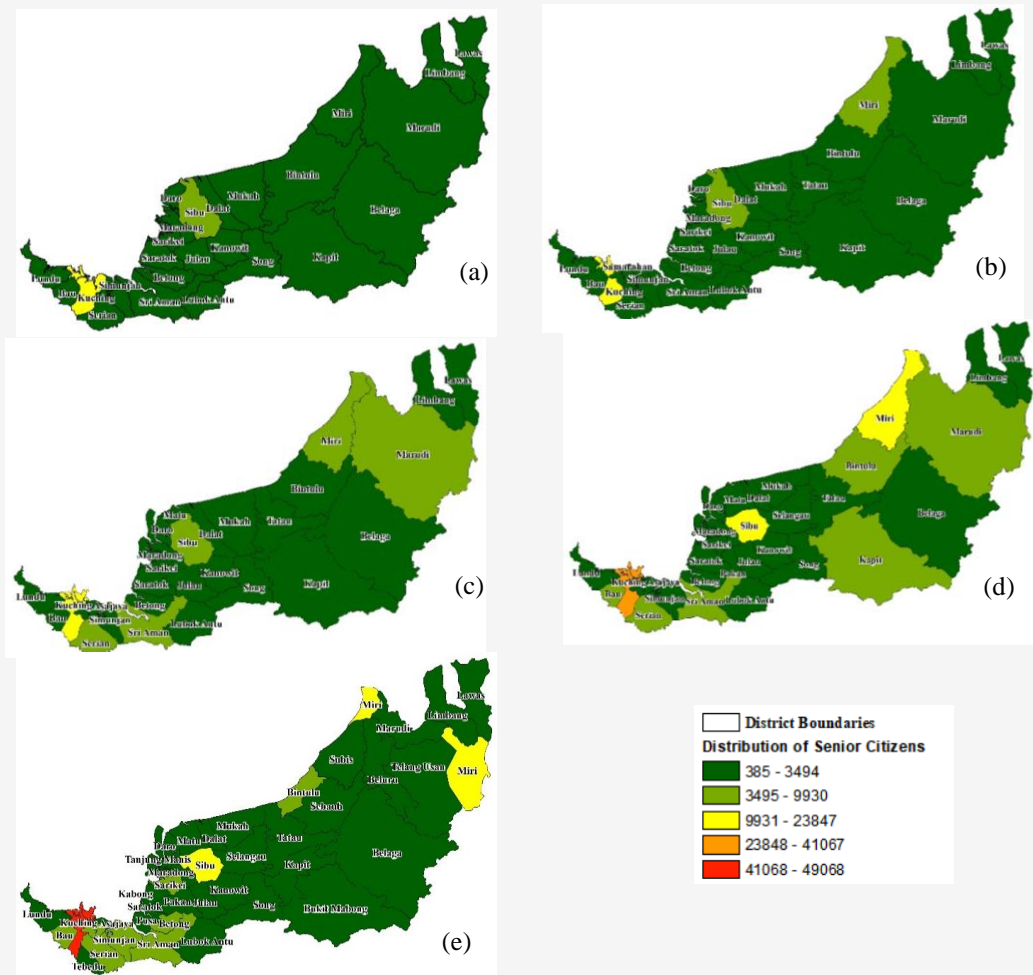

Figure 3: Spatial distribution of the elderly in Sarawak: (a) 1980 (b) 1991 (c) 2000 (d) 2010 (e) 2020
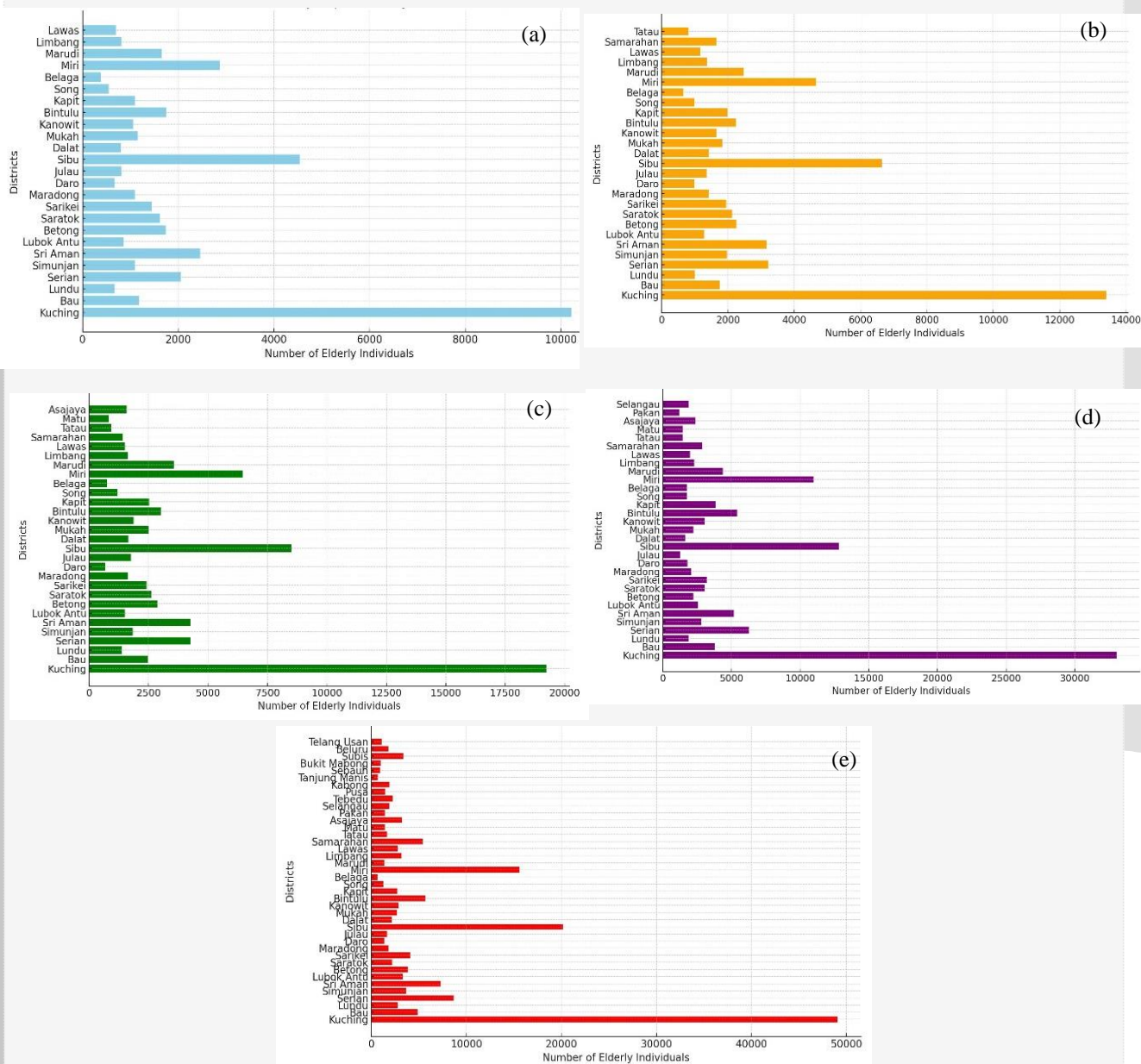
Figure 4: Elderly population in Sarawak by districts (a) 1980 (b) 1991) (c) 2000 (d) 2010 (e) 2020

The map uses a different color scheme to represent the number of seniors in a certain range in each area, as the map legend explains. The data from the Department of Statistics Malaysia (DoSM) reveal significant shifts in the elderly population across Sarawak's districts from 1980 to 2020, as depicted in Figure 4. The spatial distribution maps (Figure 3) highlight a crucial demographic transition, particularly visible in the expanding low-density elderly population zones (385-3494 range). Initially encompassing 23 districts in 1980, the stability of this low-density distribution through 2000 underscores limited changes in elderly demographics over two

decades. However, the increase to 29 districts by 2020 suggests a broader geographic spread of the elderly, potentially due to administrative boundary adjustments or shifts in population dynamics. This trend not only reflects on the spatial aspects of aging in Sarawak but also underscores the growing need for regional planning and elderly care services in newly identified low-density areas. This broadening distribution highlights the necessity for adaptive public health strategies that accommodate an aging populace across increasingly diverse and expansive rural districts.

The observed growth in the number of districts within the 3495-9930 elderly population category from one in 1980 to eight in 2020 highlights significant demographic shifts. This trend is not merely a reflection of an increasing elderly population but is indicative of broader socio-economic transformations within these regions. The expansion aligns with patterns of urbanization and enhanced healthcare accessibility noted in the literature, suggesting that regions previously less attractive to older demographics are now developing attributes that support aging populations. This shift is pivotal for understanding the changing spatial dynamics of aging in Sarawak, reinforcing findings from recent studies that emphasize the critical impact of urban development on elderly care infrastructure and accessibility [25][26] and [27]. Such insights are crucial for policymakers aiming to prioritize resources and planning efforts in districts increasingly characterized by significant elderly populations.

Next for the 9931-23847 category, only 1 district in 1980 and 1991 namely Kuching remained stable until 2000, then increased to 2 in 2010 and lasted until 2020. This district including Sibu and Miri has become an attractive city center for citizens gold, reflecting the trend of migration from rural to urban areas or the improvement of facilities and services aimed at the elderly [28]. After that, the category 23848-41067, appeared for the first time in 2010 with 1 district which is Kuching, this shows the emergence of a district with a very high number of elderly people. There are no districts in this category in 2020, which may reflect changing demographics.

Category 41068-49068, in 2020, Kuching is the only district included in the category of distribution of the most elderly, showing a very high density of elderly, which reflects the quality of services, accessibility, and infrastructure that support the lives of the elderly [29] [30] and [31].

In conclusion, this analysis reveals how the distribution of the elderly in Sarawak has changed significantly over the past 40 years. The increase in the number of areas in the low to medium category indicates a wider distribution of the elderly population, while the emergence of areas with a very high number of elderly people in 2020 indicates a significant change in the urban and social dynamics of the community area. This shows the importance of paying attention to inclusive urban and health policies for the elderly in Sarawak.

4.2 Elderly Trends Across Different Ethnic Groups (1980-2020)

Figure 5 and Table 2 show an analysis that explores the demographic changes of the elderly across different ethnic groups in Sarawak from 1980 to 2020. By using data broken down by district and ethnicity, it is possible to see changes in the proportion of the population that reflect social and demographic trends. which is wider in this country. Figure 5 above shows that throughout the period from 1980 to 2020, the Chinese ethnic group consistently holds one of the highest proportions of the elderly in the population. Starting from a prime position in 1980 with about 34.73% of the elderly population, the share declined slightly in the middle of the decade but saw a significant increase by 2020, reaching 37.73%. In contrast, ethnic Indians and other smaller ethnic groups typically have the lowest proportions, often accounting for less than 1% of the elderly population, indicating a smaller base population or different demographic trends in these communities. Based on Figure 5 and Figure 6 which show the trends in each ethnic group over time, Chinese ethnicity shows a significant increase in the later years, especially from 2010 to 2020. This increase may be due to a longer life expectancy and possibly a higher birth rate lower, a trend commonly observed in economically developed or urban societies.
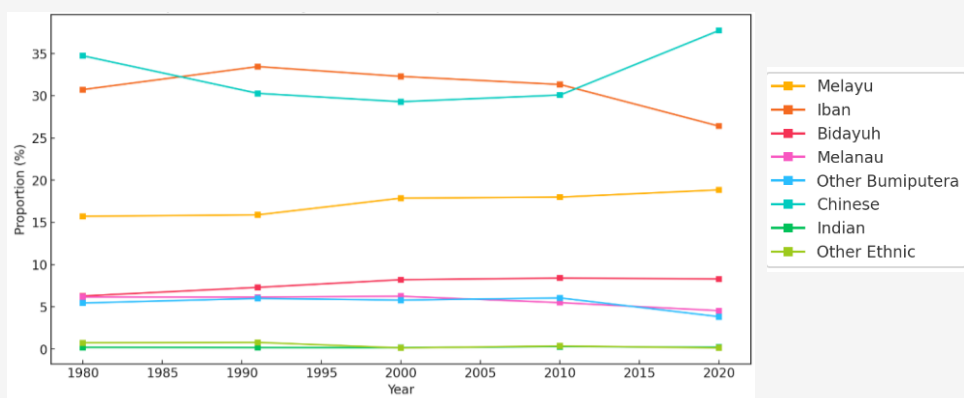

Figure 5: Trends in the percentage of elderly by ethnicity in Sarawak (1980-2020)
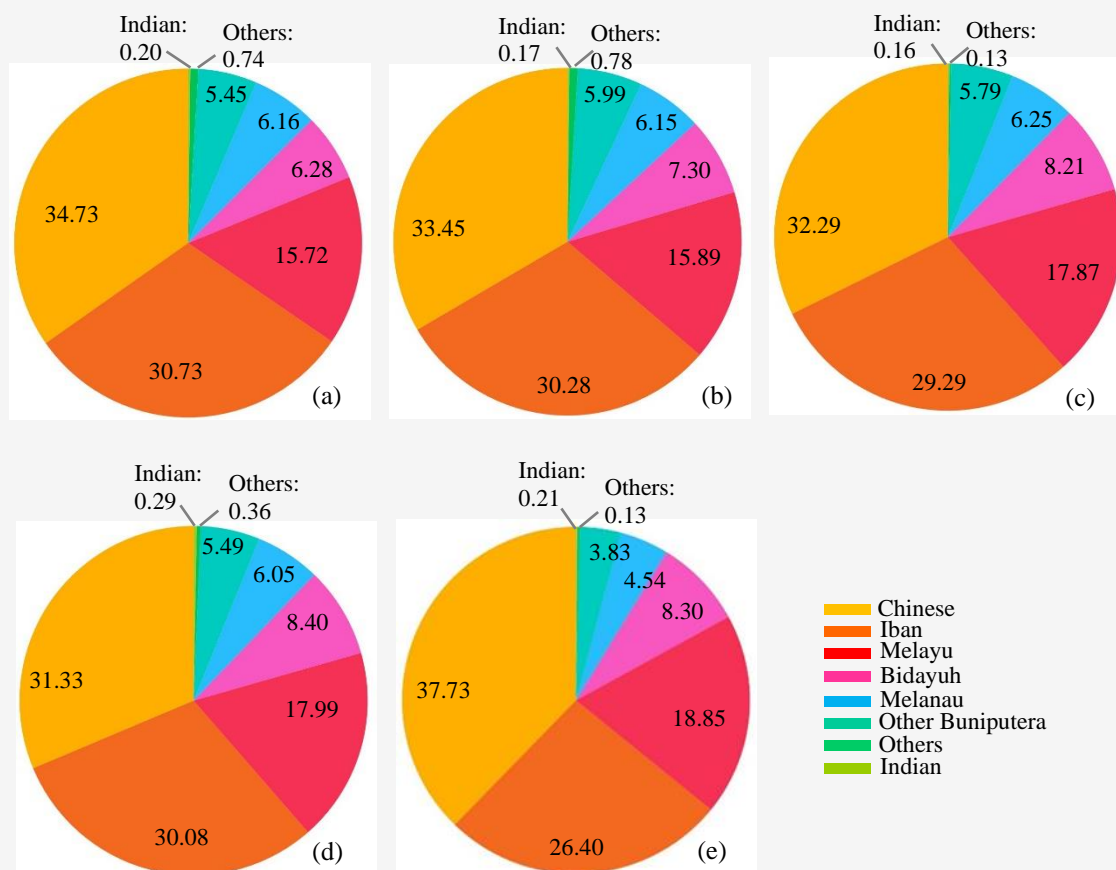
Figure 6: Proportion of elderly in ethnic groups in Sarawak (a) 1980 (b) 1991 (c) 2000 (d) 2010 (e) 2020

The Iban ethnic group, initially the group with the highest rate of elderly at 30.73% in 1980, saw a gradual decline to 26.40% by 2020. This could reflect changes in health, migration, or birth rates over the decades. Ethnic Malays and Bidayuhs show a gradual increase in their proportion of elderly people. Ethnic Malay increased from 15.72% in 1980 to 18.85% in 2020, and Bidayuh from 6.28% to 8.30% in the same period, indicating an aging population in this ethnic group. Although Melanau and Other Bumiputera Groups experience slight fluctuations but generally show a downward trend in the share of the elderly population by 2020.

4.3 Comparison Across Different Ethnic Groups
Trends across different ethnic groups reveal both similarities and significant differences. For example, the Chinese and Malay communities, both showing an increase in the proportion of elderly individuals, may face similar challenges such as the need for better healthcare services and elderly care facilities [32]. However, the rate of increase and the overall proportion of ethnic Chinese are higher, which may

require more targeted strategies in health care planning and community services.

In contrast, the Iban and other indigenous groups such as the Melanau show a decrease or more stable but lower trend in the proportion of elderly people. These differences may reflect varying socio-economic conditions, cultural norms regarding family size, or different access to health care and lifestyle choices that affect life expectancy [33] and [34]. In conclusion, the changing demographics of Sarawak's elderly population highlight the need for tailored approaches in public health, social services, and economic planning to accommodate an increasingly diverse aging population. The variation between different ethnic groups underscores the importance of culturally sensitive policies and demographic information to ensure that all seniors receive the support and services they need. In an analysis of trends in the proportion of elderly people by ethnicity in Sarawak from 1980 to 2020, a linear regression model provides data that quantitatively reveals how this proportion has changed over forty years.
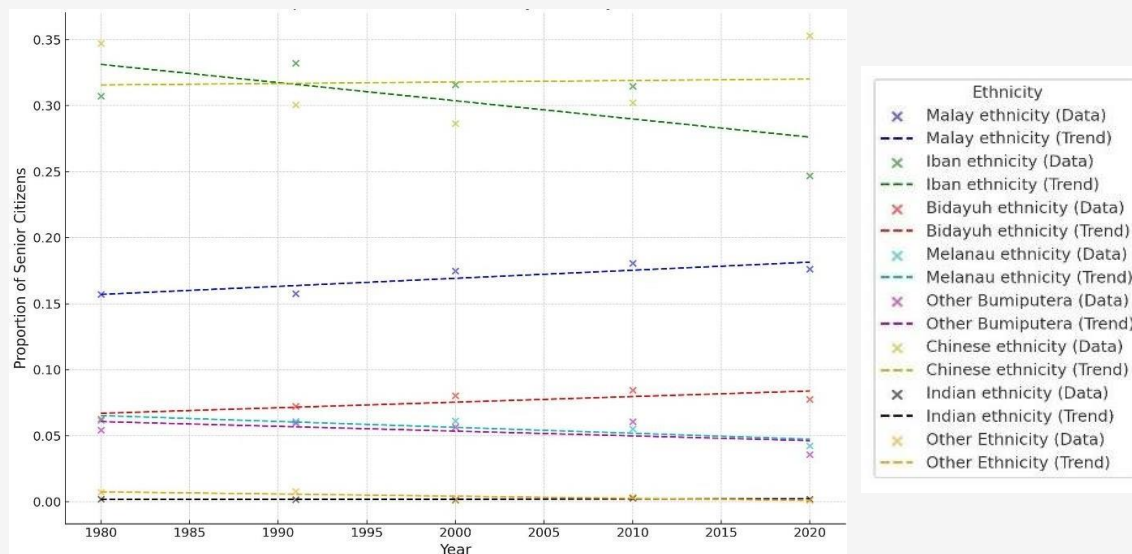
Figure 7: Trends of elderly by ethnicity in Sarawak (1980-2020)

Table 2: Linear regression analysis of elderly proportions by ethnicity (1980- 2020)

Ethnicity	Slope	P-value	R-squared
Malay	0.00061	0.05	0.75
Iban	-0.00138	0.22	0.43
Bidayuh	0.00042	0.11	0.63
Melanau	-0.00045	0.06	0.73
Other Bumiputera	-0.00036	0.33	0.31
Chinese	0.00011	0.92	0.003
Indian	0.00001	0.54	0.13
Other Ethnicity	-0.00016	0.09	0.65

Figure 7 and Table 2 show the results from the linear regression analysis of the proportion of elderly people from 1980 to 2020. Regression analysis shows a positive trend in the proportion of elderly for Malay ethnicity, with a slope $(\beta 1)$ of 0.00061. This shows that every year, the proportion of elderly for the Malay ethnicity increases by 0.061%. The intercept $(\beta 0)$ of this regression line shows that in 1980, the base year of the research, the elderly Malays were at the starting point calculated by the regression model. The p-value associated with Malay ethnicity is 0.05, which is at the conventional peak for statistical significance, suggesting a meaningful but marginal trend. The R-squared value of 0.75 indicates that 75% of the variability in the proportion of elderly for the Malay ethnic group over the years can be explained by the model, indicating a strong fit.

On the other hand, the Iban ethnicity shows a downward trend, with a slope of - 0.00138. This shows a decrease of 0.138% every year in the proportion of Iban ethnic elderly. The relatively high p-value of 0.22 indicates that this negative trend is not statistically significant, implying that the annual change may be due to random variation or other

unmodelled factors. The R-squared value of 0.43 indicates that the model explains less than half of the variation in the Iban data, pointing to other potential influences on the proportion of Iban ethnic elderly.

The trend line for ethnic Chinese elderly has a very slight positive slope of 0.00011, indicating a nearly stable proportion throughout the year with a minimal annual increase of 0.011%. However, the p-value of 0.92 shows that this trend is not statistically significant, indicating no significant year-to-year change. Furthermore, the R-squared value of 0.003 indicates that the model does not effectively explain the variation in the proportion of ethnic Chinese elderly, suggesting that other variables may be at play. The same analysis for the Bidayuh and Melanau ethnicities shows a small but different trend. The Bidayuh ethnicity has a positive gradient, while Melanau people show a negative gradient, each showing a subtle annual change in their respective proportion of elderly. The p-values for these ethnicities indicate that the trend is not statistically strong, which is further supported by their R-squared values which indicate moderate explanatory power of the model for this group.

For Indian ethnicity, the linear regression results show a very slight positive trend, with a slope of 0.00001, suggesting an annual increase in the proportion of ethnic Indian elderly by 0.001%. Despite this growth, the changes were minimal and not statistically significant, as indicated by the p-value of 0.54. An R-squared value of 0.13 implies that only 13% of the variation in the proportion of ethnic Indian elderly can be accounted for by year, indicating that factors not included in the model may significantly influence this trend. This shows a stable proportion of elderly people in ethnic India, with little variation explained by time alone. Other Bumiputera ethnicities, which include various other indigenous groups not classified under the main ethnic label, show a negative trend in the elderly ratio, with a slope of -0.00036. This represents an annual decrease of 0.036% in their share. A p-value of 0.33 indicates that this downward trend is not statistically significant, suggesting that the observed annual decline may be due to chance or external factors not captured by the model. The R-squared value of 0.31 indicates that approximately 31% of the variability in the proportion of elderly among Other Bumiputeras is explained by the model, suggesting moderate fit, and indicating the presence of other influencing factors beyond annual changes.

Based on all ethnic groups, the analysis revealed various trends in aging patterns among Sarawak's ethnic communities over the past forty years. Ethnic Malays and Bidayuh show a positive trend, showing an increasing proportion of elderly people, although with varying levels of statistical significance and model fit. In contrast, the Iban, Melanau, and Other Bumiputera ethnicities show a negative trend, with the decrease in their proportion of elderly not statistically significant, suggesting that additional variables may need to be considered to fully understand this pattern. The minimal changes observed in Chinese and Indian ethnicities, combined with low R-squared values, indicate that the proportion of elderly in these ethnicities is influenced by factors that are not accounted for by year alone. This analysis underscores the difficulty of demographic aging in Sarawak's ethnically diverse population, highlighting the need for targeted studies and policies that consider the unique circumstances and needs of each ethnic group.

5. Discussion

5.1 Interpretive Analysis of Results

The analysis of population distribution trends by ethnic group in Sarawak from 1980 to 2020 provides a comprehensive view of the demographic dynamics across several decades.

The variations in growth, decline, and stability of the elderly population among different ethnic groups underscore the influence of a range of social, economic, and health factors over time. This study identifies significant disparities in the aging trends among ethnic groups, highlighting the complex interplay of these factors in shaping demographic patterns.

The Chinese ethnic group in Sarawak has seen a marked increase in the proportion of elderly individuals, a trend that could be attributed to higher life expectancies and improved access to healthcare services, particularly in urban areas where such facilities are more concentrated. This aligns with previous studies indicating that urbanization and enhanced healthcare provision are pivotal in driving population aging [5] and [35]. Tobler's First Law of Geography supports this finding by suggesting that the clustering of elderly populations in urban centers such as Kuching and Miri are influenced by better socio-economic conditions. Conversely, the Iban ethnic group has experienced a decline in the proportion of elderly individuals, potentially due to rural-to-urban migration that typically involves younger people relocating to cities for employment opportunities, consequently reducing the elderly demographic in rural settings. This shift corroborates literature that identifies migration as a significant determinant of rural demographic structures [36]. The proximity to economic opportunities in urban areas appears to play a crucial role in these demographic trends.

For the Malay ethnic group, an upward trend in the elderly ratio can be linked to improvements in healthcare and socio-economic conditions over the past four decades. Research suggests that enhanced healthcare accessibility and higher living standards contribute to increased life expectancy, a pattern observed across Malaysia [37] and [38]. This trend reflects a broader national progression towards an aging population, especially among ethnic groups benefiting from improved socio-economic resources. The stable proportion of elderly among the Chinese and Indian ethnic groups might reflect the impact of cultural practices and social structures that support elder care within family settings. The principle of filial piety, particularly prevalent in Chinese culture, might contribute to maintaining a stable elderly ratio despite socio-economic shifts [39] and [40]. This stability indicates that cultural factors, alongside geographic and community support systems, are influential in the demographic patterns observed. Furthermore, the decline in elderly populations within the Iban and Other Bumiputera groups may also be driven by migration patterns.

The movement of younger individuals towards urban areas for better employment prospects leads to a diminished elderly population in rural areas, reflecting broader socio-economic changes in Sarawak [36]. This shift underscores the need to consider migration's effects on aging populations, particularly in rural and remote regions.

While the Malay and Melanau ethnicities display statistically significant trends, the high p-values observed in other ethnic groups suggest that changes in the elderly proportion over time may not be solely time-related. These findings underscore the necessity to incorporate additional variables such as economic conditions, migration, and cultural practices in the models, which current methodologies may not fully capture. The variable R-squared values further suggest that the models for certain ethnic groups, such as the Chinese and Indians, do not adequately explain the influences on their elderly populations, highlighting the complex nature of demographic dynamics that extend beyond temporal factors alone [41]. In applying Tobler's First Law, we have mapped the distribution of elderly populations across Sarawak, noting that districts with close geographic proximity often exhibit similar demographic trends. This observation aligns with Tobler's principle by demonstrating that neighboring districts tend to share more demographic characteristics than those that are further apart. For instance, urban areas like Kuching and Miri show similar aging trends, which could be influenced by shared socio-economic developments and healthcare facilities, underscoring the practical application of Tobler's Law in our interpretative framework.

5.2 Implication of Study

The findings from this study underscore the urgent need for tailored socio-economic planning and public health strategies across Sarawak, with a particular focus on adapting to the ethnic diversity within the aging population. As urban areas see a rising number of elderly, especially among the Chinese and Malay communities, there is a clear directive for increasing healthcare resources, including specialized geriatric care and dementia-friendly facilities, which cater to the nuanced needs of these groups. Additionally, the significant shifts in birth rates and age structures observed suggest potential challenges for workforce sustainability and economic vitality, particularly in districts with high proportions of ethnic groups like the Iban, who are experiencing faster aging rates. Strategic initiatives are thus required not only to bolster the workforce but also to integrate elderly individuals into the community and economy, potentially through senior volunteer programs or part-time employment opportunities tailored to their capabilities and cultural preferences [42].

This study also highlights the critical importance of integrating spatial analysis and ethnic-specific demographic trends into public policy frameworks. Policies must be context-sensitive, recognizing the distinct socio-economic backgrounds of Sarawak's diverse regions. For example, while urban centers may require infrastructure upgrades to support an increasingly elderly population, rural areas—where ethnic communities such as the Bidayuh and Melanau or other ethics reside—need investments in transportation and mobile health services to ensure accessibility to essential services. The geographic and demographic insights provided by this research advocate for a more segmented approach to policymaking, where resources are allocated not just based on population size but on the specific needs and characteristics of each ethnic group. Aligning spatial and demographic analyses with public policy initiatives offers a pathway to more effectively tackle the challenges posed by an aging population. By ensuring that policy interventions are attuned to the cultural and socio-economic realities of Sarawak's various ethnic groups, the region can achieve more sustainable socio-economic development and enhance the quality of life for all its citizens. This approach not only promises to create a more inclusive society but also strengthens the public health system to better serve the diverse needs of an aging populace.

6. Conclusion

In conclusion, the analysis of elderly population distribution in Sarawak from 1980 to 2020 highlights significant demographic shifts across all ethnic groups, underscoring the influence of spatial and socio-economic factors as outlined by Tobler's First Law of Geography. These findings are crucial for formulating effective, inclusive policies tailored to the aging population's needs, enhancing our understanding of demographic dynamics in ethnically diverse and geographically varied regions. Thus, while our study does not incorporate detailed spatial statistical analyses, the use of Tobler's First Law remains justified as it supports the interpretation of spatial distribution patterns observed. It also highlights the importance of geographic proximity in the analysis of demographic data, providing a solid theoretical framework for understanding and discussing our findings. This study not only contributes to the broader discourse on population aging but also underscores the importance of integrating geographic and socio-economic considerations in demographic research and policymaking, offering valuable insights for future studies and interventions.

7. Limitations and Future Research

While this study has offered significant insights into the demographic shifts in Sarawak, it is important to acknowledge its limitations. One of the primary constraints is the potential inadequacy of the data to fully capture internal migration patterns or the nuanced socio-economic factors that impact different ethnic groups. These elements are crucial for understanding the complete landscape of demographic changes and their implications. Future research should adopt a more integrated approach that combines both qualitative and quantitative methodologies. Qualitative data could provide richer, contextual insights into the personal and community-level effects of demographic trends, while quantitative analysis would allow for the broader generalization and identification of patterns across the population. This mixed-methods approach would enable a deeper understanding of the underlying drivers of demographic shifts and the specific challenges faced by various ethnic groups.

Moreover, investigating the influence of regional policies on demographic changes could yield valuable information on how these trends can be more effectively managed. This could involve comparative studies of different regions within Malaysia to ascertain the impact of specific policies and interventions on aging populations. Understanding the efficacy of various policy approaches could guide the formulation of targeted strategies that address the unique needs of Sarawak's diverse communities. Additionally, longitudinal studies could track these demographic trends over a longer period to assess the long-term effects of current policies and socio-economic conditions. Such studies would provide insights into the sustainability of interventions and the evolving needs of the population.

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